

Rhode Island Sea Grant >>

# RI Shoreline Change Special Area Management Plan

*the* Beach  
SAMIP



# Three Threats the Plan will Address

- Sea Level Rise
- Storm effects
- Erosion

These forces interact in a synergistic fashion that adds to their destructive force.

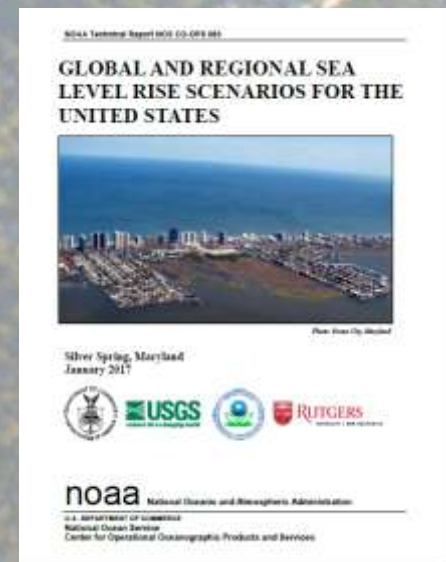
For example one foot of sea level rise jumps the recurrence level so that the once in one hundred year storm now has a return probability of one in fifty. Two feet and that jumps once in 25 years and 5 feet is like having a once 100 year storm once a day.

# New NOAA Estimate from Report Released January 2017

- Just released NOAA predicts a Global High Estimate for the Newport tide gage the 83% confidence interval of 9.6 feet. For the built environment we need to consider a Extreme High Tide events that can add to 1.5 to 2 feet to the average high tide, this then would essentially be 12 feet by 2100.

From the report: “The growing evidence of accelerated ice loss from Antarctica and Greenland only strengthens an argument for **considering worst-case scenarios in coastal risk management.**”

Extreme GMSL by 2200 projected to be 9.7M (31.8 feet). This SLR scenario will inundate most every coastal city worldwide.











# Flood Zones(2009, left and 2013, right) Misquamicut Barrier

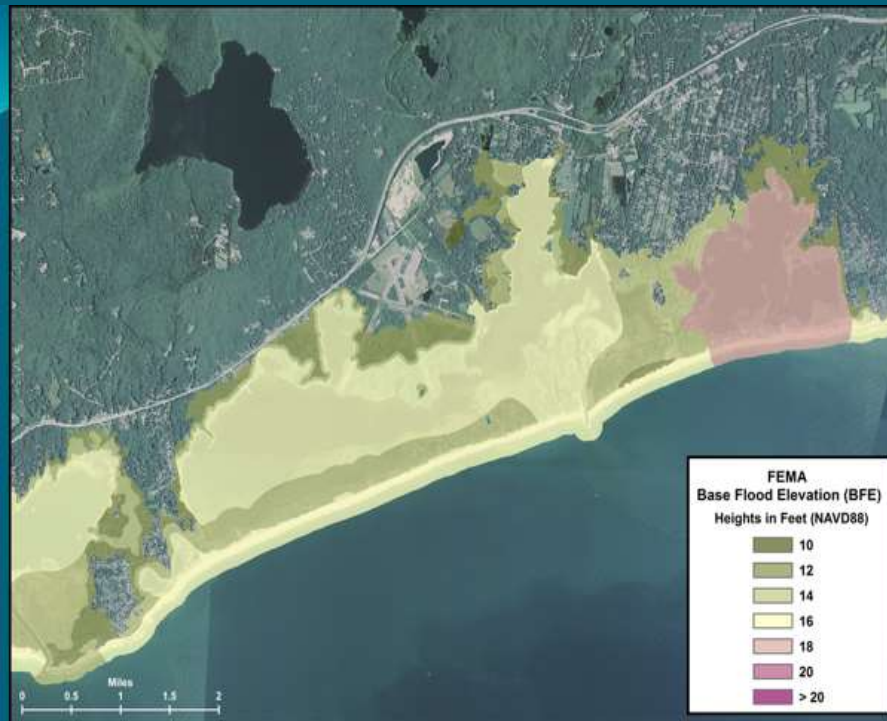


2-3 ft reduction in BFE

# Technical Issues with FEMA FIRMs

These maps are made by consulting firms using assumptions that do not reflect Rhode Island conditions.

- **For example there is an assumed dune profile that FEMA contractors default to called the 540 rule. This dune profile is much larger than our actual dunes. In fact, the 540 dune is larger in volume in a post storm condition, than our dunes are before the storm.**
- **FEMA has under estimated the wave conditions offshore. The wave conditions are used as the input value for their transect model. The recent maps have offshore waves from a 100 year event at 4 meters. Hurricane Irene which was a 25 year event generated waves offshore of 4.2 meters. The data and model runs for offshore conditions in our area show that a 100 year event should be 8 meters. Thus they are using half of the value that should be used to run the transect models.**
- Too few transects to represent spatial variability in the study area (violates FEMA guidance)
- 1 D wave model (FEMA) cannot capture 2-D wave processes (STWAVE).

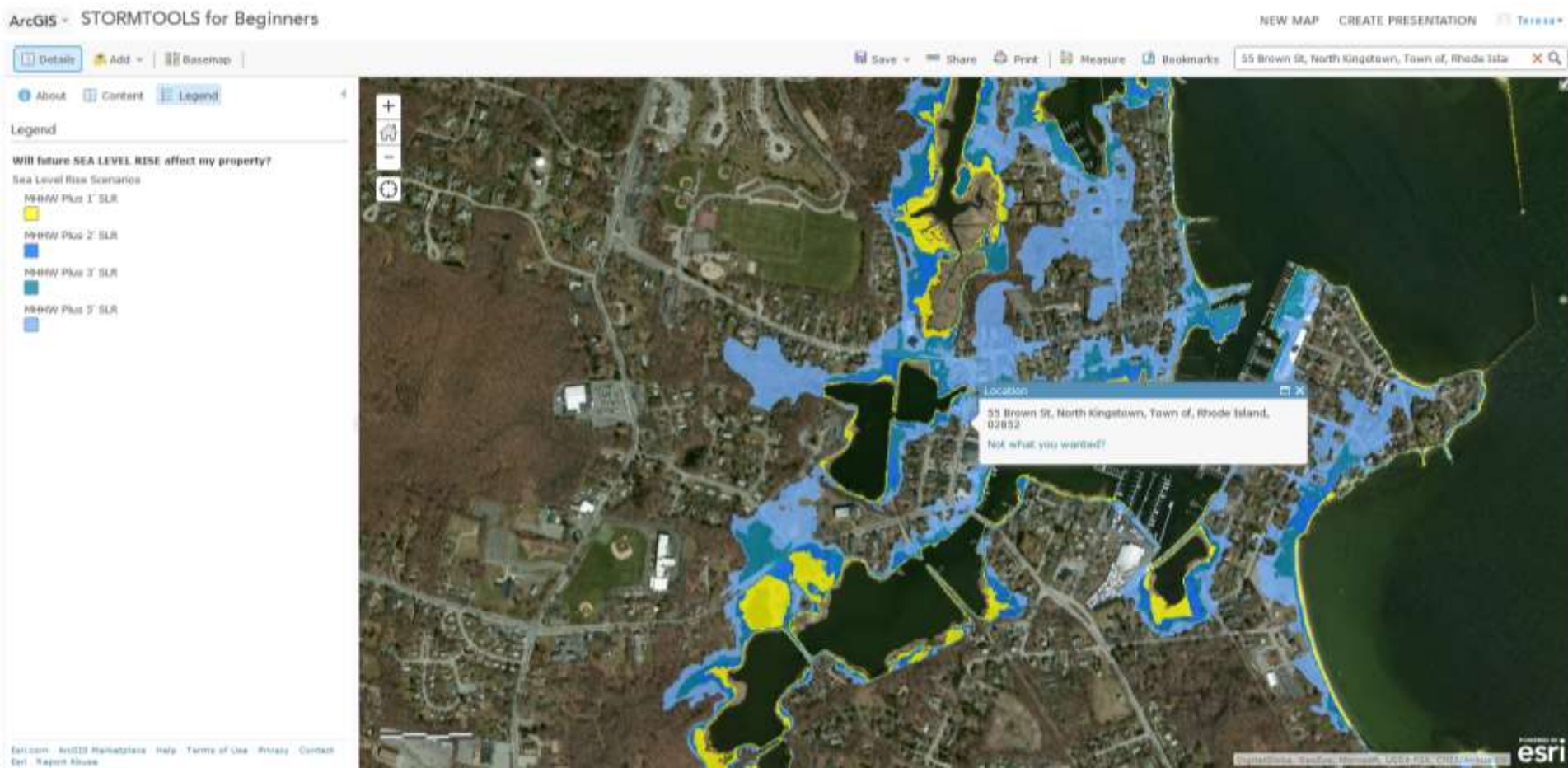


# “STORMTOOLS FOR BEGINNERS”

Step 1: Enter an address

Step 2: Click on the question you want to answer

*“Will future SEA LEVEL RISE affect my property  
(with 2 tides per day, every day)?”*  
(sea level rise scenario map)



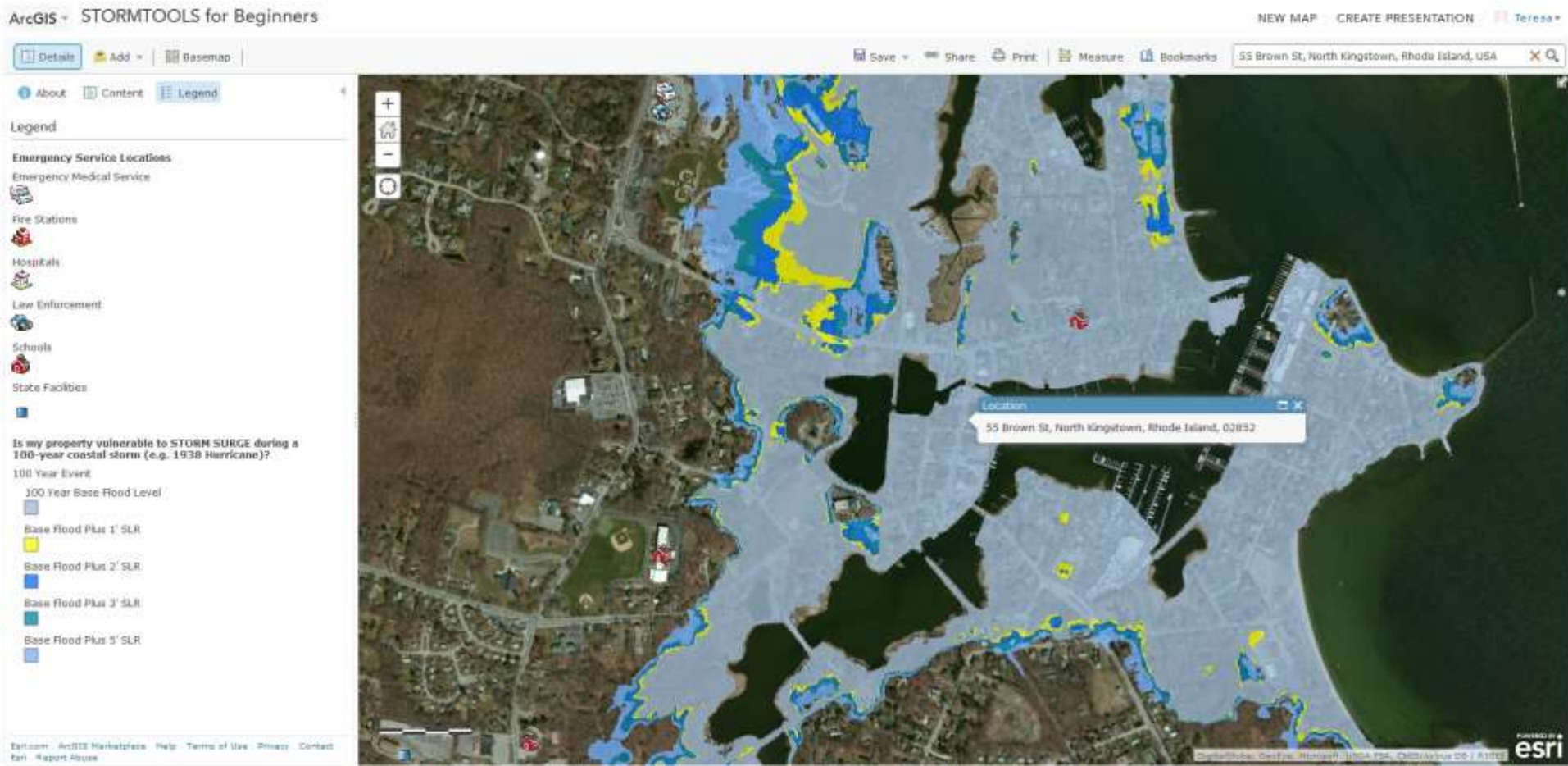
# “STORMTOOLS FOR BEGINNERS”

Step 1: Enter an address

Step 2: Click on the question you want to answer

***“Is my property vulnerable to STORM SURGE during a 100-year coastal storm (e.g. 1938 Hurricane)?”***

**(flood extent map)**

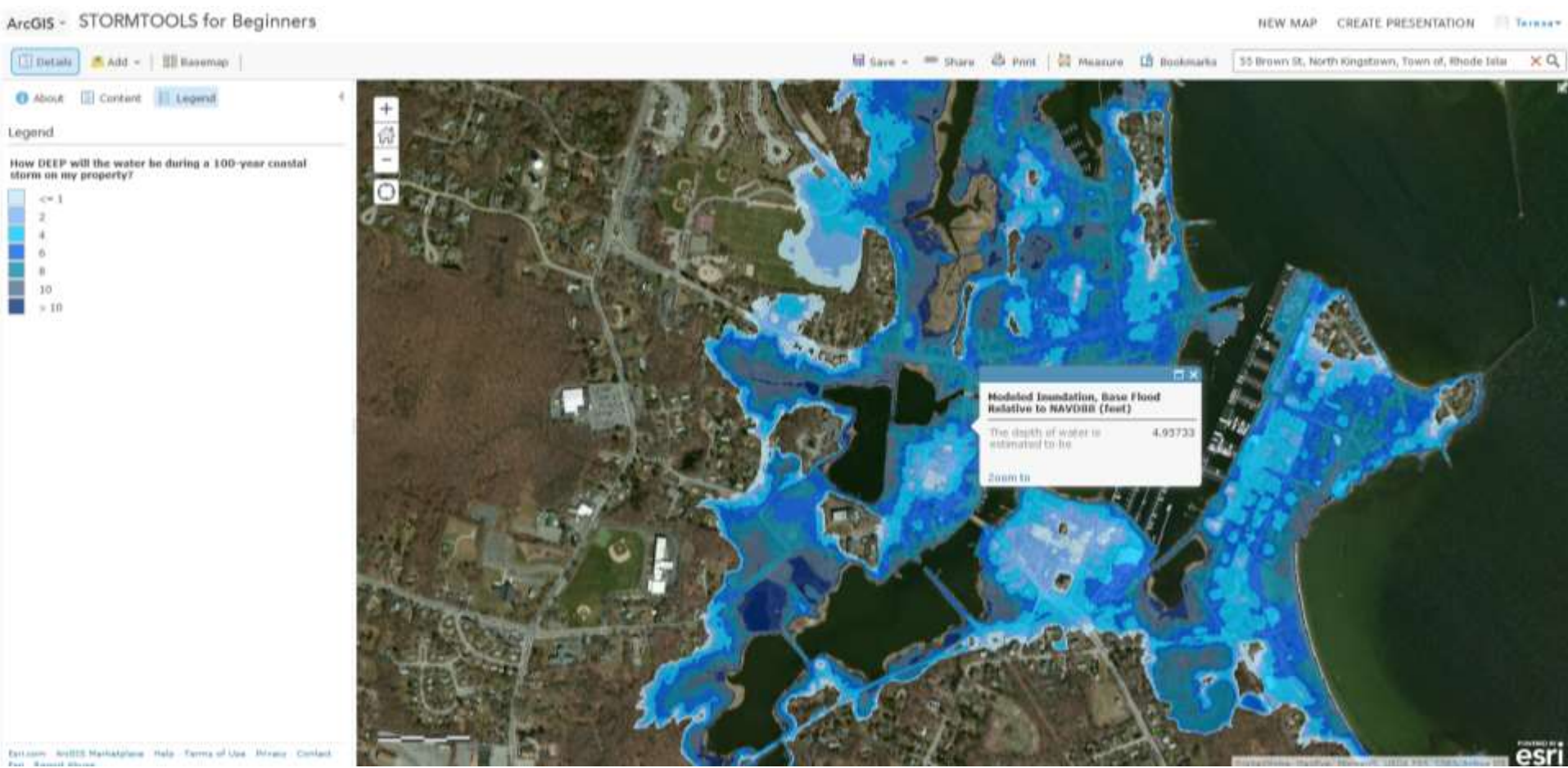


# “STORMTOOLS FOR BEGINNERS”

Step 1: Enter an address

Step 2: Click on the question you want to answer

*“How DEEP will the water be during a 100-year coastal storm on my property?”*  
(water depth map)



# **NEW STATEWIDE ANALYSIS FOR EVERY STRUCTURE IN THE STATE SLR AND STORM SCENARIOS**

- **Sea Level Rise (feet)**
  - 1, 2, 3, 5, 7
- **Storm Return Period (year)**
  - 10, 25, 100, 500
- **Sea Level Rise & Storm Inundation**
  - SLR1(10,25,100) - SLR5 (10,25,100)
  - SLR2 (10,25,100) - SLR7 (10,25,100)
  - SLR3 (10,25,100)

# Assessment of Coastal Inundation 100 Year Storm Event 7 foot Sea Level Rise

Surge inundation used in this analysis excludes the existence of the Fox Point Hurricane Barrier, located in the Providence area upriver, and was considered non-certified (in FEMA parlance). SLR scenarios are still valid as the barrier will not be closed except during these storm events.

## Map Legend

Density of Inundated Structures  
(number per square mile)

Coastal Towns

< 200

200 - 500

501 - 1,000

> 1,000



0 2.5 5 7.5 10

Kilometers

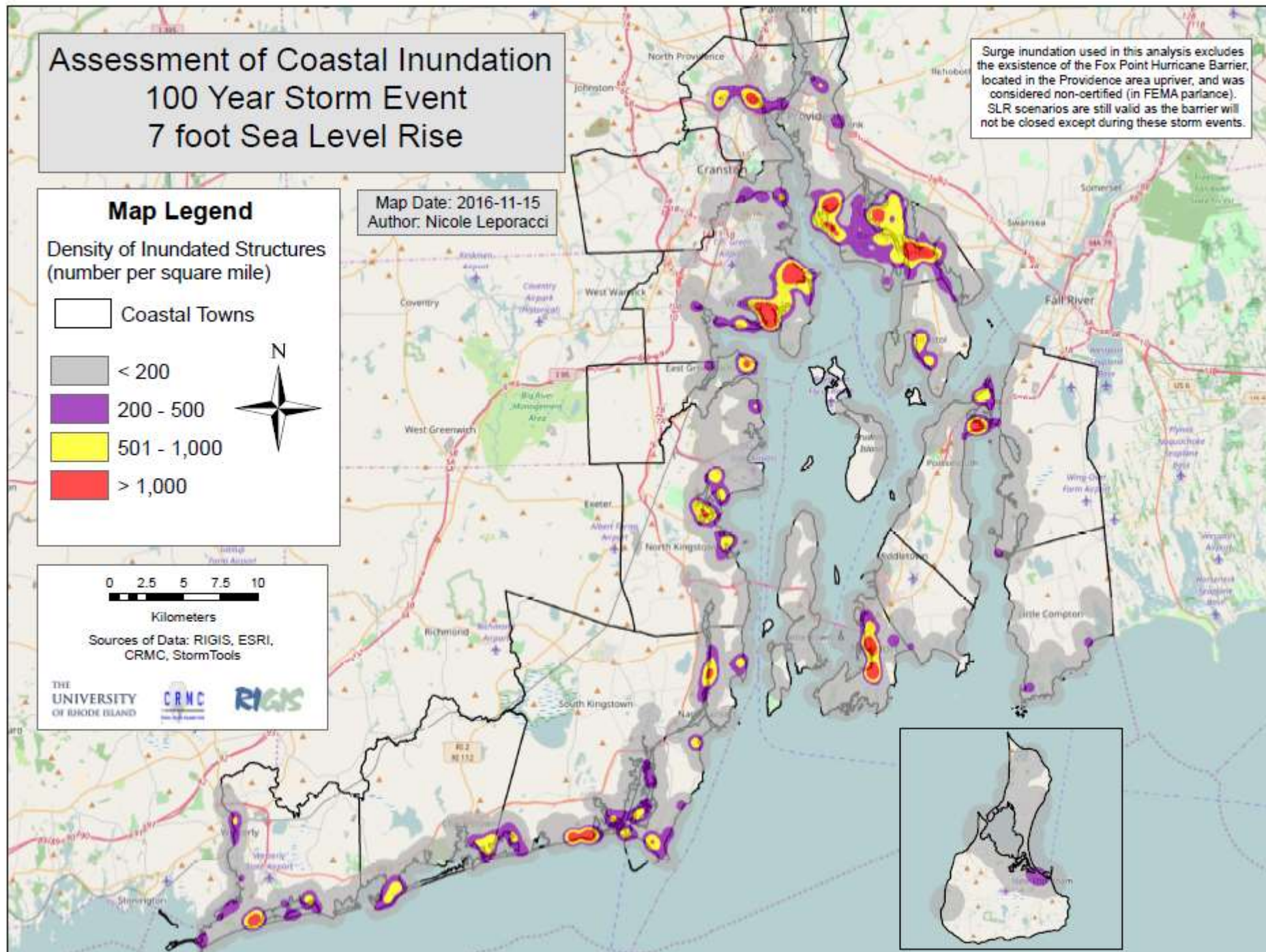
Sources of Data: RIGIS, ESRI,  
CRMC, StormTools

THE  
UNIVERSITY  
OF RHODE ISLAND

CRMC  
Coastal Resource  
Management Center

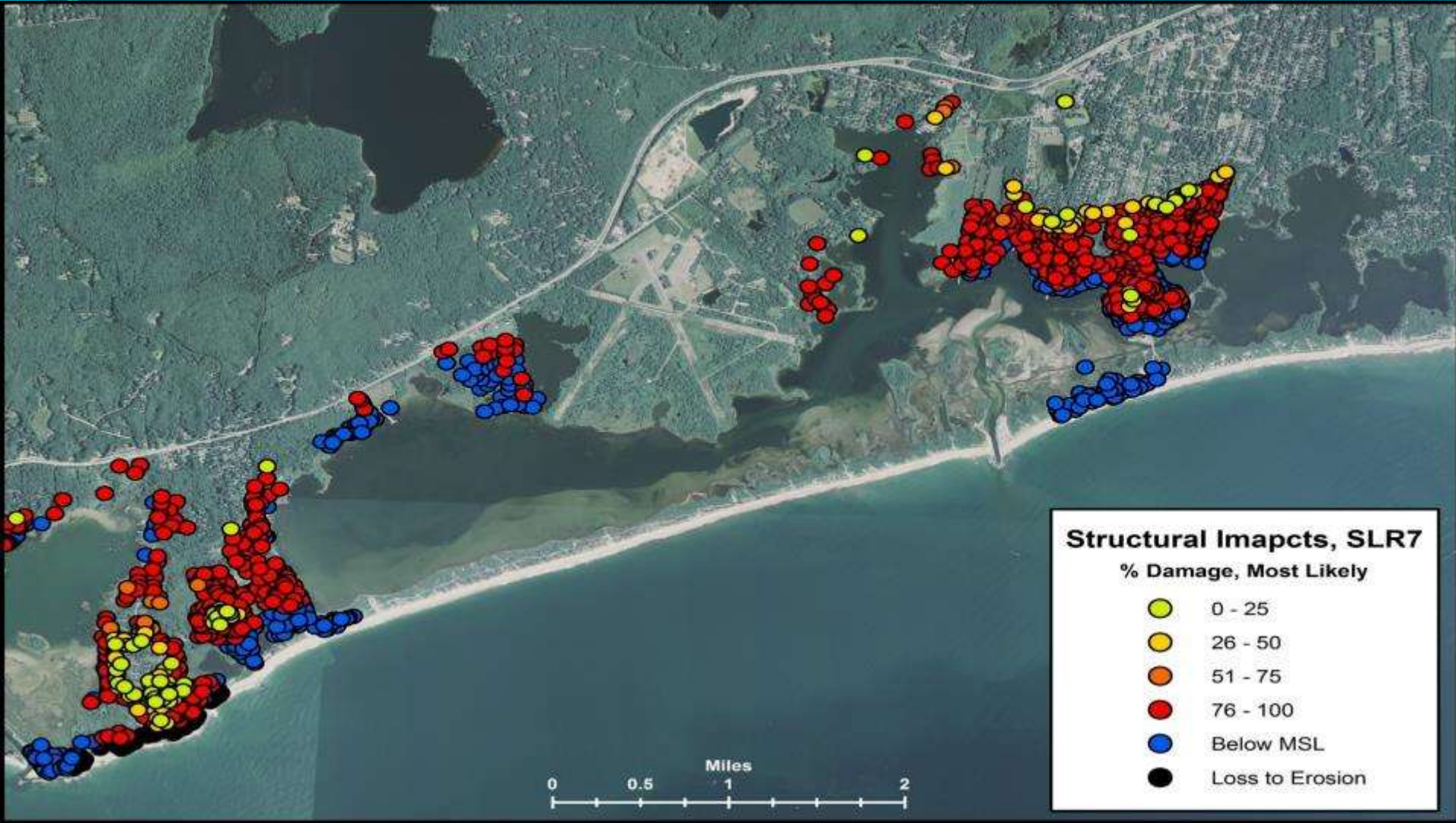
RIGIS  
Rhode Island Geographic  
Information System

Map Date: 2016-11-15  
Author: Nicole Leporacci

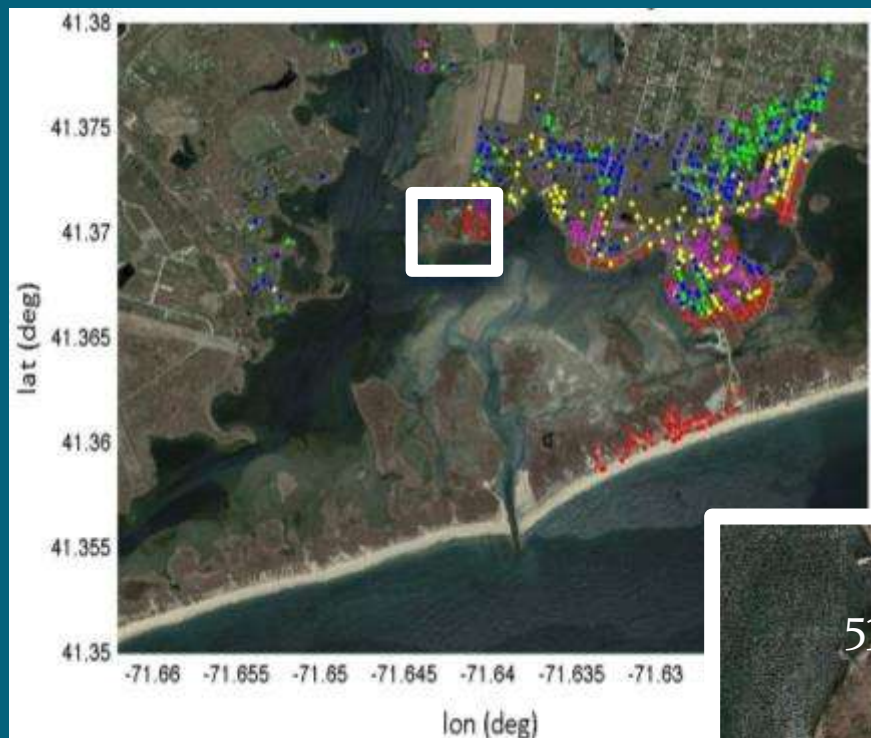








## DAMAGE ESTIMATION - CLOSE UP



## HOUSE PARAMETERS

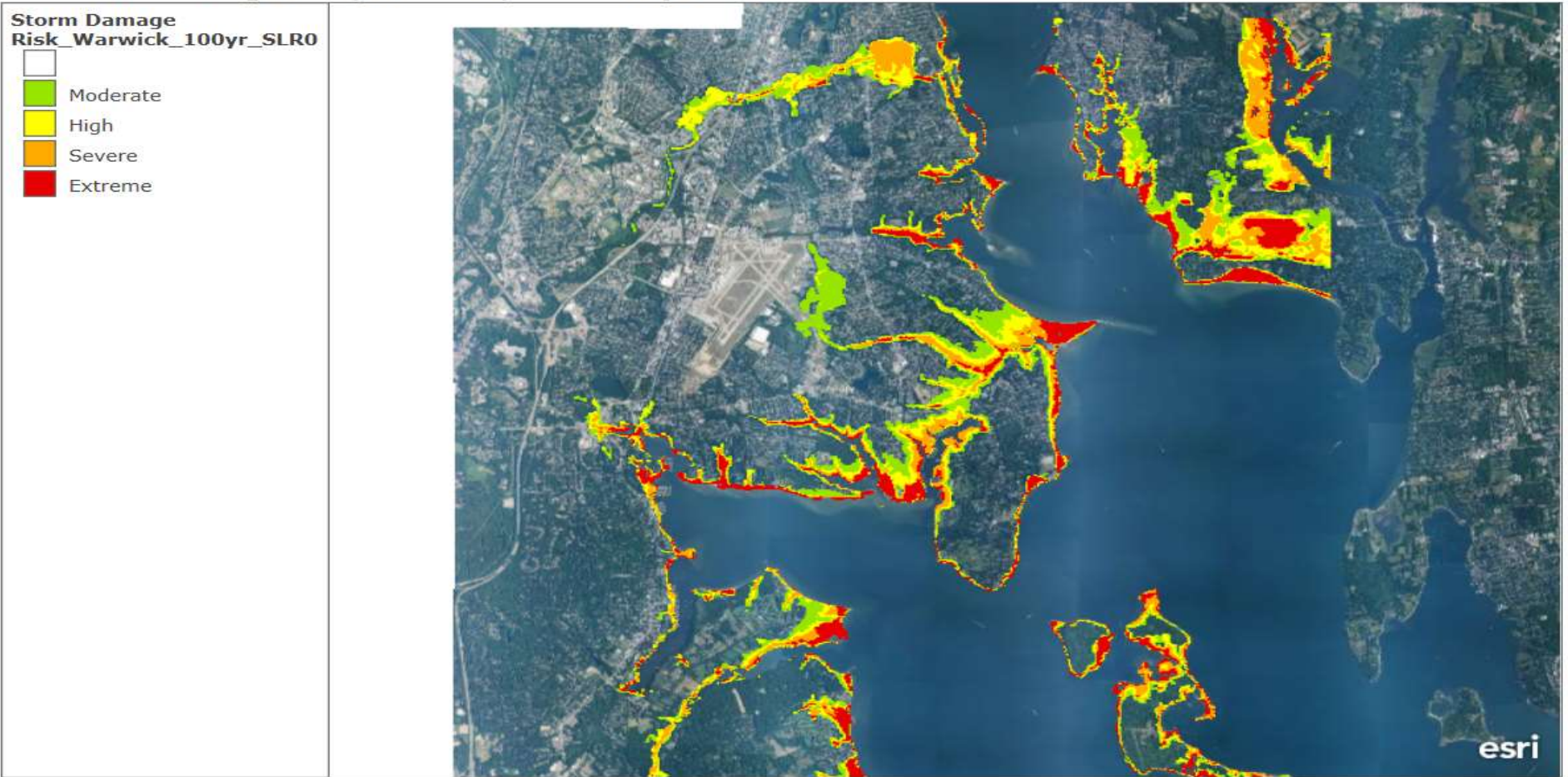
ID			HOUSE	FFE
	LON	LAT	TYPE	(m)
5391	-71.6432	41.3706	6B	0.6
5413	-71.6423	41.3700	6B	0.6
5418	-71.6417	41.3702	6B	0.6
5470	-71.6416	41.3705	6B	0.6
5425	-71.6415	41.3707	5A	0.6
5473	-71.6410	41.3709	6B	0.6

## ENVIRONMENTAL PARAMETERS

TOPO DEM (M)	SURGE NAVD88	WAVE	
		CREST NAVD88	WAVE HEIGHT
1.7	4.8	5.8	1.0
2.5	4.8	5.9	1.1
2.7	4.8	5.8	1.0
2.9	4.8	5.8	1.0
2.9	4.8	5.7	1.0
2.5	4.8	5.7	1.0

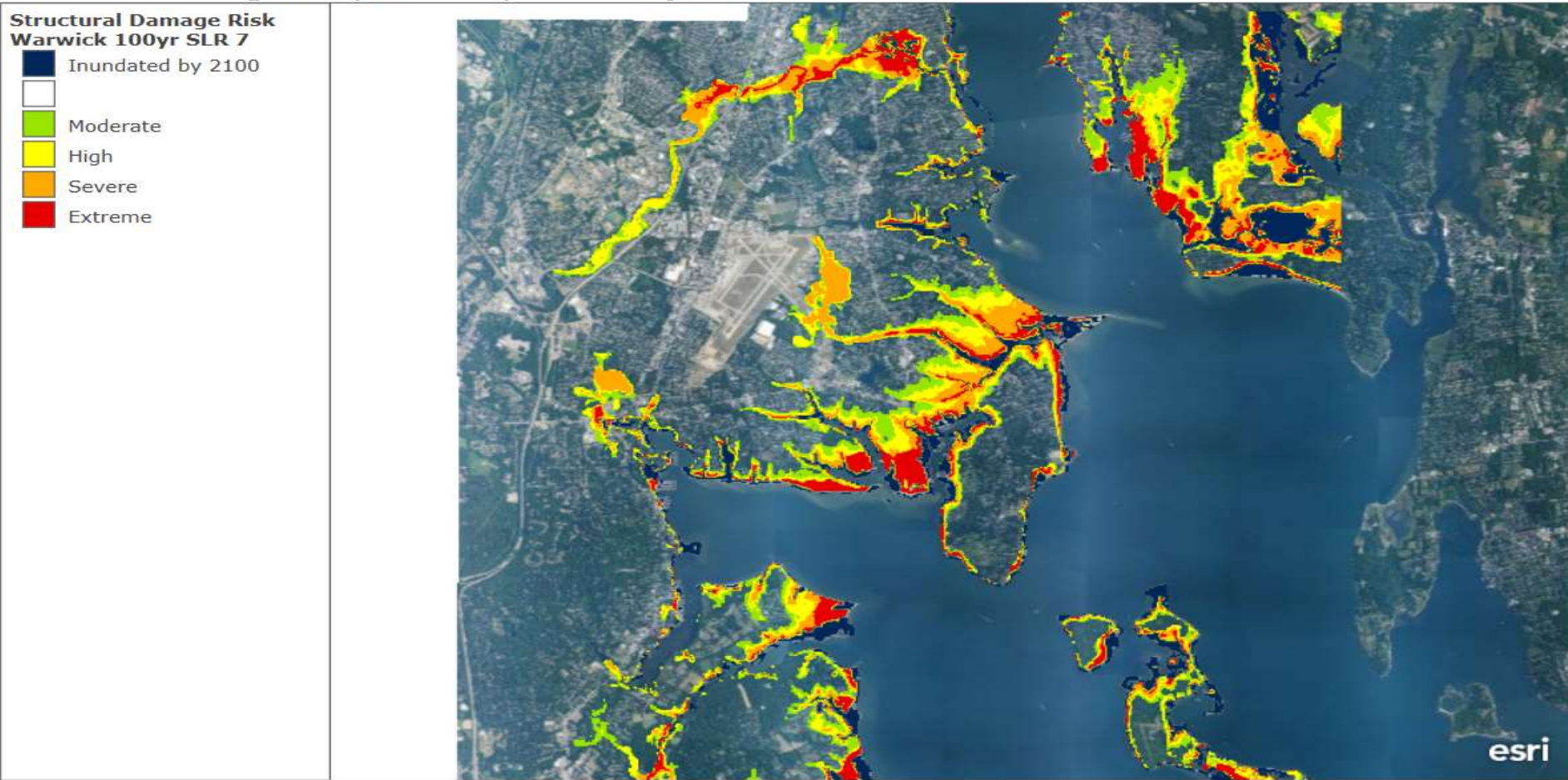


Structural Damage Risk, Warwick, CERI 100yr SLR 0



Structural Damage estimates for Warwick, RI

Structural Damage Risk, Warwick, CERI 100yr SLR7



Structural Damage Estimates, Warwick RI 100yr SLR7

## Projected amount of groundwater rise with 6.6 feet of sea-level rise

# Assessing the Effects of Rising Groundwater from Sea Level Rise on the Service Life of Pavements in Coastal Road Infrastructure

Jayne F. Knott, Mohamed Elshaer, Jo Sias Daniel, Jennifer M. Jacobs, and Paul Kirshen

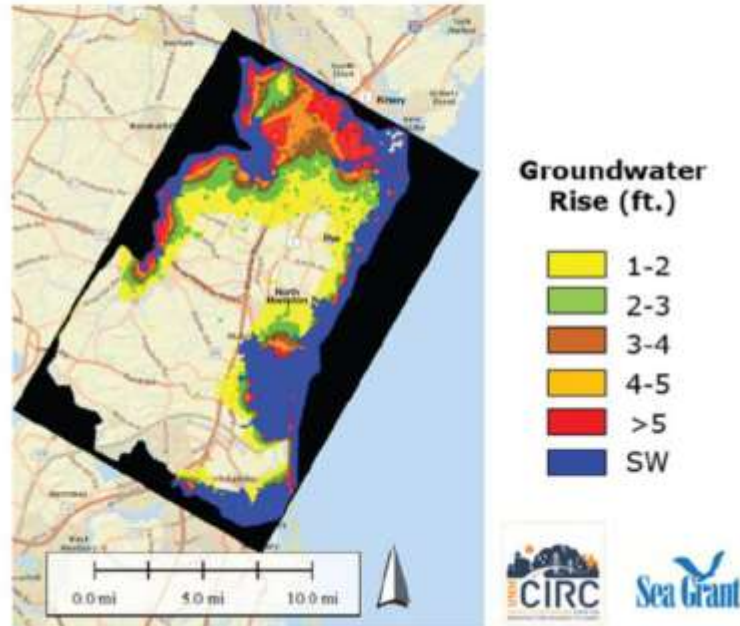
Coastal communities with road infrastructure close to the shoreline are vulnerable to the effects of sea level rise caused by climate change. The sea level in coastal New Hampshire is projected to rise by 3.9 to 6.6 ft (1.2 to 2.0 m) by 2100. Climate change vulnerability and adaptation studies have focused on surface water flooding caused by sea level rise; however, little attention has been given to the effects of climate change on groundwater. Groundwater is expected to rise with sea level rise and will intersect the unbound layers of coastal road infrastructure, thus reducing the service life of pavement. Vulnerability studies are an essential part of adaptation planning, and pavement engineers are looking for methods to identify roads that may experience premature failure. In this study, a regional groundwater flow model of coastal New Hampshire was used to identify road infrastructure for which rising groundwater will move into the unbound materials during the design life of the pavement. Multilayer elastic theory was used to analyze typical pavement profiles in several functional classifications of roadway to determine the magnitude of fatigue and rutting life reduction expected from four scenarios of sea level rise. All the evaluation sites experienced service life reduction, the magnitude and timing of which depended on the current depth to groundwater, the pavement structure, and the subgrade. The use of this methodology will enable pavement engineers to target coastal road adaptation projects effectively and will result in significant cost savings compared with implementation of broad adaptation projects or the costs of no action.

Coastal areas worldwide are becoming more developed. Roads, constructed to service the built environment along the shore, are increasingly at risk from sea level rise, more intense coastal storms, and storm surge (1). Although the shoreline in many locations could be fortified in the future to protect property from coastal storms, access roads in coastal communities are vulnerable to rising groundwater caused by sea level rise. The sea level in coastal New Hampshire is

projected to rise by 3.9 to 6.6 ft (1.2 to 2.0 m) by 2100. Water is expected to rise with rising sea level not only at the coast but also at significant distances inland (3, p. 46). Tides, rising groundwater caused by sea level rise will unbound layers of coastal road infrastructure, weaken pavement structure. Pavement design criteria currently is based on stationary or, on average, not changing with time. Research in climate change science have shown that the climate is stationary. Transportation engineers, concerned that design criteria of the past are no longer valid, are looking for guidance for designing and restoring pavement system changes in groundwater levels will change the frequency and severity of road failures as well as the time and cost of repairs.

Sea level rise can cause erosion and storm surge damage, flood coastal communities, and damage coastal infrastructure (4). The causes of sea level rise are (a) thermal expansion of ocean waters, (b) water transfer between glaciers and oceans, (c) vertical land movement, (d) shifts in the Earth's magnetic field, and (e) ocean dynamics (5). There is uncertainty in projections of sea level rise in part because no one knows how quickly global economies will reduce greenhouse gas emissions and because the ice-loss dynamics of the Greenland and West Antarctica ice sheets are not well understood. A study linking global sea level rise to global-temperature-projected global sea level rise ranging from 2.5 to 6.2 ft (0.76 to 1.9 m) between 1990 and 2100 (6). The National Oceanic and Atmospheric Administration (NOAA) assessed several studies of sea level rise and produced scenarios of global mean sea level rise ranging from 0.7 (0.2 m) to 6.6 ft by the end of this century (5). The lowest figure is an extrapolation of the historical record, and the highest is based on the Intergovernmental Panel on Climate Change AR4 projections of global sea level rise combined with an estimate of the maximum amount of glacial and ice sheet loss by the end of the century. NOAA recommended that the 6.6-ft scenario be used to design infrastructure where the tolerance for risk is small (5). In coastal New Hampshire, the sea level rose 5.3 in. (13.5 cm) between 1927 and 2001, close to the global mean sea level rise. The New Hampshire Hazards and Risks Commission has adopted the NOAA scenario for coastal adaptation planning (2).

In coastal areas, groundwater flows from recharge areas to discharge areas along the shoreline. As sea level rises, the groundwater levels near the coast also rise, until a new equilibrium is established between aquifer recharge and groundwater discharge to the sea.



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Transportation Research Record: Journal of the Transportation Research Board, No. 2639, 2017, pp. 1-10.  
http://dx.doi.org/10.3141/2639-01

# CERI Building Blocks

- **Water levels** (100 yr.. or specific storm event) for flooding, with or without SLR, available from **STORMTOOLS**.  
(<http://www.beachsamp.org/resources/stormtools/>)
- **Wave estimates** (100 yr..) for flood inundated areas, with and without SLR based on state of the art wave models.
- **Shoreline change** (erosion/accretion) estimates based on most recent 2016 RI CRMC shoreline change maps.
- **Damage functions** by structure or infrastructure type based on data from superstorm Sandy (2012) (US Army Corp of Engineers(ACOE)/FEMA)).
- **Location/identification** of individual structures and infrastructure from E911 and town and state data bases.

## CHAPTER 5

### RI CRMC Coastal Hazard Application Guidance

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#### Overview of Process

The steps presented below provide guidance for applicants to address Coastal Hazards for selected projects in the design and permitting process for the Rhode Island Coastal Resources Management Council (CRMC).

#### STEP 1: PROJECT DESIGN LIFE

In this step, the applicant will choose an appropriate design life, or lifespan, for the project, and identify a projected sea level for the project site based on the selected design life.

#### STEP 2: SITE ASSESSMENT & BASE FLOOD ELEVATION

In this step the applicant will review specified maps and tools to assess the exposure and potential risk from coastal hazards at the project site.

#### STEP 3: LARGE PROJECTS

This step is for Large Projects and Subdivisions only. If not such a project, this step may be skipped.

#### STEP 4: DESIGN EVALUATION

The applicant will identify, document, and assess the feasibility of design techniques that could serve to avoid or minimize risk of losses.

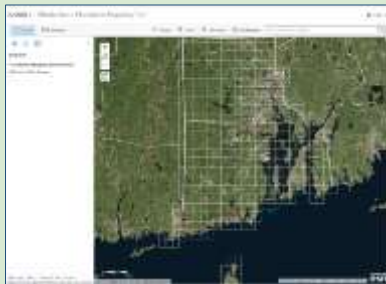
#### STEP 5: SUBMIT AN APPLICATION

The applicant will submit the permit application and include the assessment from the previous steps in the application package to the CRMC.

# Rhode Island's MAPPING TOOLBOX

## Past and Present

### 1. RIEMA Floodplain Mapping Tool



### 2. Coastal Erosion



## Future

### 3. STORMTOOLS



### 4. SLAMM

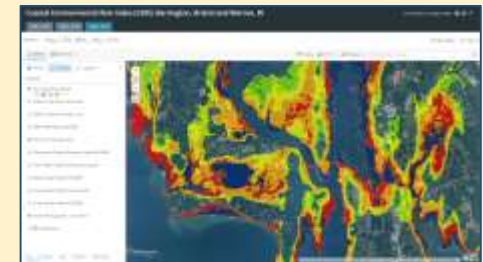


### 5. MyCoast



## Future

### 6. Coastal Environmental Risk Index (CERI)



### 7. STORMTOOLS Design Elevation



### 8. RICRMC Coastal Hazard Viewer





## RI Coastal Resources Management Council

...to preserve, protect, develop, and restore coastal resources for all Rhode Islanders



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### Coastal Hazard Application

Welcome to the RICRMC Coastal Hazard Application WORKSHEET and ONLINE VIEWER!

Please download and print the **RICRMC Coastal Hazard Application WORKSHEET** from the link below, and use the **ONLINE VIEWER** to access the maps and other information required for completion of the **WORKSHEET**.



Coastal Hazard Application Worksheet (PDF)  
Coastal Hazards Application – Interactive Form (PDF)

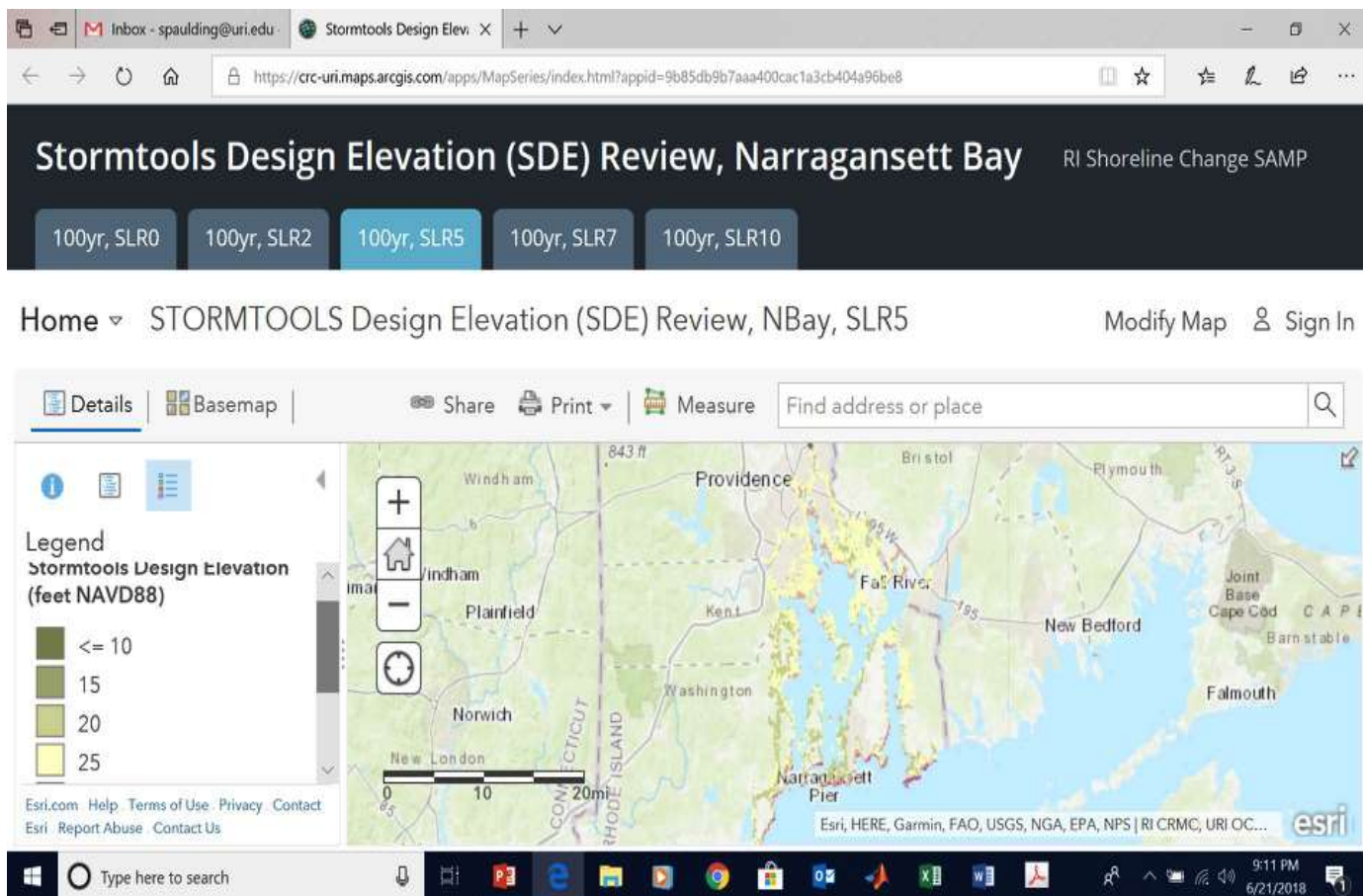


Coastal Hazards Application Online Viewer

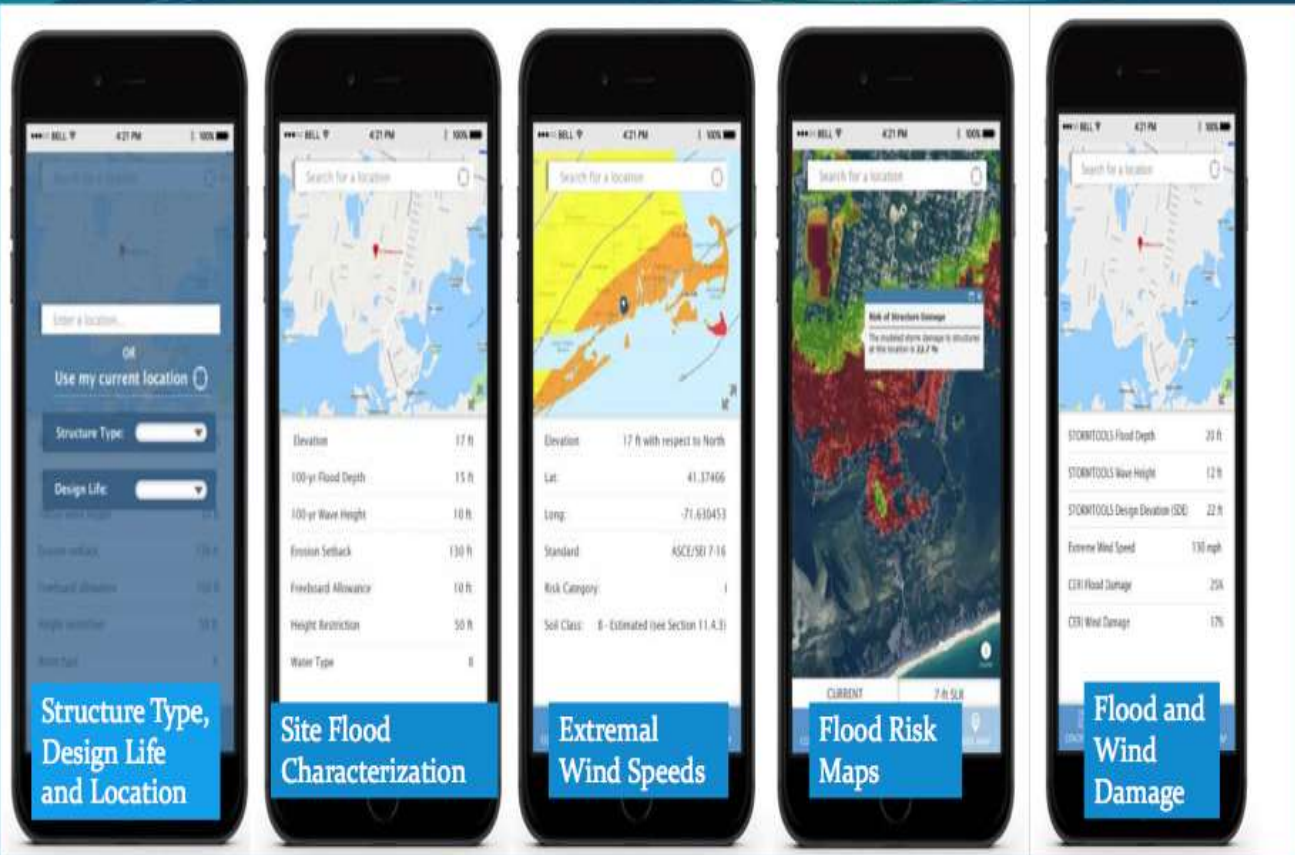
The list of projects below must complete the RICRMC Coastal Hazard Application WORKSHEET to be filed in addition to and with your standard CRMC application (<http://www.crmc.ri.gov/applicationforms.html>).

Any of the following **new projects**, including tear downs and rebuilds, located on a coastal feature or within the 300-foot contiguous area:

1. construction of new residential buildings as defined in § 1.1.2;
2. construction of new commercial and industrial structures as defined in § 1.1.2;
3. construction of new beach pavilions as defined in § 1.1.2;
4. construction of any new private or public roadway, regardless of length;
5. construction of any new infrastructure project subject to §§ 1.3.1(f), (h), and (i); and
6. construction of any new subdivisions with six (6) or more lots, any portion of which is within 200 feet of a shoreline feature.



## The future: CERI Risk and Damage App(start Oct 2018)



This project required a coastal hazards analysis as per the Rhode Island Coastal Resources Management Council's regulations. The Council recommends residential applications meet a minimum of a 30 year design life..

Please be advised this project with a stated FFE of 17.23':

- does meet the anticipated rate of Sea Level Rise (SLR) (for 30 years/3' SLR)
- does meet applicable the accelerated erosion rate setback
- does not meet the recommended StormTools Design Elevation (SDE) for three feet (3') of SLR.
- does not meet the StormTools Design Elevation (SDE) recommended for the submitted/CHA design life of 50 years/5' of SLR.

## ARTICLE OPEN

## Hurricane stalling along the North American coast and implications for rainfall

Timothy M. Hall<sup>1</sup> and James P. Kossin<sup>2</sup>

The average speed of tropical cyclone (TC) translation has slowed since the mid 20th century. Here we report that North Atlantic (NA) TCs have become increasingly likely to “stall” near the coast, spending many hours in confined regions. The stalling is driven not only by slower translation, but also by an increase in abrupt changes of direction. We compute residence-time distributions for TCs in confined coastal regions, and find that the tails of these distributions have increased significantly. We also show that TCs stalling over a region result in more rain on the region. Together, increased stalling and increased rain during stalls imply increased coastal rainfall from TCs, other factors equal. Although the data are sparse, we do in fact find a significant positive trend in coastal annual-mean rainfall 1948–2017 from TCs that stall, and we verify that this is due to increased stalling frequency. We make no attribution to anthropogenic climate forcing for the stalling or rainfall; the trends could be due to low frequency natural variability. Regardless of the cause, the significant increases in TC stalling frequency and high potential for associated increases in rainfall have very likely exacerbated TC hazards for coastal populations.

npj Climate and Atmospheric Science (2019) 2:17 | <https://doi.org/10.1038/s41612-019-0074-8>

## INTRODUCTION

A TC's trajectory largely determines its hazard. The most obvious example is whether or not a TC makes landfall and, if so, where. Another factor affecting hazard is the length of time a TC resides in a region near the coast; i.e., whether the TC “stalls” near the coast. A stalling TC inflicts strong winds on the same region for a longer time, potentially driving greater storm surge and depositing more rain.

Recent analysis of observations indicates that the average translation speed of TCs has slowed globally since the mid 20th century, including overland regions of the North Atlantic (NA) domain.<sup>1</sup> TC trajectories are largely determined by the steering of large-scale mid-tropospheric circulation patterns and a generally smaller beta effect due to gradients in planetary vorticity that induces a poleward drift.<sup>2</sup> Research is conflicted concerning the evolution of the atmospheric circulation in response to anthropogenic climate forcing. Some modeling and observational analyses suggest a weakening of general atmospheric circulation patterns, including those of the tropics.<sup>3–6</sup> In one study, simulated TCs using climate-model-projected circulation changes indicate reduced westward steering flow in the NA subtropics and a consequential reduction in westward moving tracks compared to recurving tracks,<sup>7</sup> though elsewhere in the NA the projected changes in the magnitude of steering flow are negligible. Another recent study found that the translation speed of NA TCs is reduced under climate-change scenarios.<sup>8</sup> By contrast, other work, including high-resolution doubled-CO<sub>2</sub> modeling experiments<sup>9</sup> and downscaled CMIP3 and CMIP5 late-21st-century modeling experiments,<sup>10</sup> find no significant change in TC track speed.

In the mid-latitudes, some results suggest that a reduction in meridional temperature gradients due to arctic amplification has reduced the speed and increased the waviness of mid-tropospheric zonal winds<sup>11–13</sup> in winter as well as summer.<sup>14</sup>

These weaker and more variable winds provide less robust steering flow for TCs and allow blocking patterns to persist longer. However, there is considerable debate on the robustness of the signal and the physical mechanisms.<sup>15,16</sup>

Taken together, there is not at present a clear mechanism explaining the observed TC speed reduction. Nonetheless, the observation of slower TC translation<sup>1</sup> has the potential for elevating hazard, and it is worthwhile exploring its impacts. One key impact is that slower TCs are more prone to stalling, and stalling TCs have the potential for depositing damaging amounts of rain. This trajectory-induced increase in rainfall is exacerbated by the climate-warming impact on the hydrologic cycle. Increased atmospheric moisture enhances the likelihood of extreme rainfall events of all types.<sup>17,18</sup> Close to the center of a TC, the increases in rain rate can reach 10% per degree C of warming in some model projections,<sup>19</sup> exceeding the 7% dictated by the Clausius-Clapeyron relationship. There is evidence that TC rainfall has increased over the southeastern US in recent decades, both absolutely and as a fraction of extreme rainfall on the Continental United States (CONUS).<sup>20</sup> Hurricane Harvey's catastrophic flooding of 2017 was a tragic example of a stalled TC over extremely warm ocean water that produced record rainfall.<sup>21</sup> According to recent studies, a significant fraction (9–37%) of Harvey's rainfall was due to a warming climate,<sup>22,23</sup> and the frequency of Harvey-like rainfall events is projected to increase substantially by the late 21st century.<sup>24</sup>

Here we define a stalling metric for TCs and report that the stalling frequency of NA TCs has increased significantly in coastal regions since the mid 20th century. We then show that accumulated TC rainfall increases with increased TC residence over a coastal region. Together, the observations that the frequency of stalls has increased and that stalling TCs accumulate more rain imply an increase in rainfall from TCs, other factors

<sup>1</sup>NASA Goddard Institute for Space Studies, New York, NY, USA and <sup>2</sup>NOAA National Centers for Environmental Information, Center for Weather and Climate, Madison, WI, USA  
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# Seven years of 500-year storms

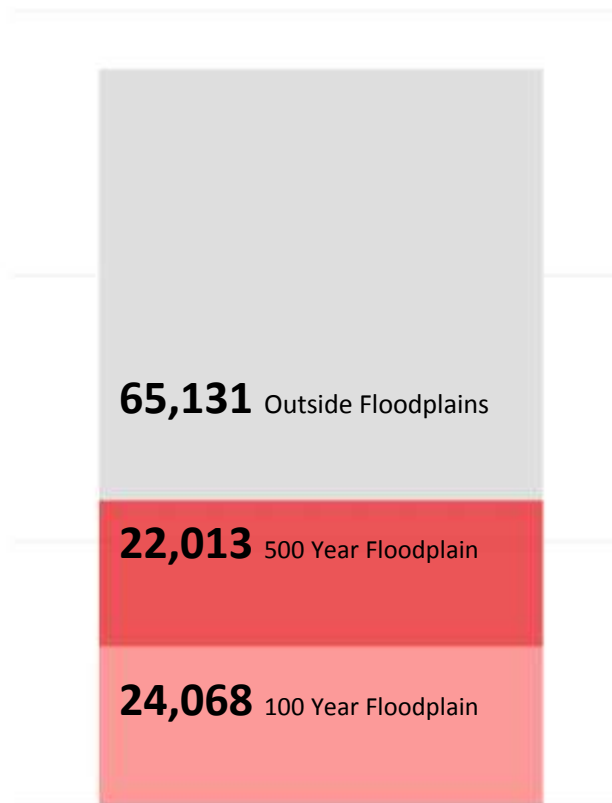
Locations of major 500-year rains since 2010 analyzed by the Hydrometeorological Design Studies Center of the National Weather Service

Houston's has been hit with 6, 500 year events since 2010 and two of those are likely to be considered 1000 year events.



## Where Harris County properties flooded by Harvey were located:

More properties outside of the floodplains flooded during Harvey than within the floodplains.



Source: Houston Public Works

Note: These numbers exclude properties in Buffalo Bayou and San Jacinto Watersheds that were impacted by the reservoir releases.

Credit: Connie Hanzhang Jin

# Hurricane Michael

- Mexico Beach was ground zero for Hurricane Michael, destroying 70 percent of the resort community's homes and businesses with its Category 5 winds and 18-foot storm surge.
- 80 percent of those structures were uninsured because FEMA placed them in flood zone "X" , according to a report by My Flood Risk, an affiliate of Melbourne, Fla.-based National Flood Insurance LLC.

0 ft Sea Level Rise with 100 year storm						
Zone	Exposed Parcels	Value Exposed (\$)	Total Parcels (Town)	Total Value (Town)	Percent Exposed (Town)	Percent Value (Town)
Residential	1520	\$ 1,061,129,300.00	5493	\$ 2,333,463,700.00	27.7%	45.5%
Business	26	\$ 11,924,600.00	273	\$ 92,829,700.00	9.5%	12.8%
Civic	10	\$ 9,968,600.00	22	\$ 22,865,800.00	45.5%	43.6%
Undeveloped	63	\$ 15,802,700.00	132	\$ 49,987,700.00	47.7%	31.6%
Other	0	\$ -	56	\$ 20,620,200.00	0.0%	0.0%
No Zoning	14	\$ 29,300.00	62	\$ 506,200.00	22.6%	5.8%
Totals:	1633	\$ 1,098,854,500.00	6038	\$ 2,520,273,300.00	27.0%	43.6%

## Marsh Elevation Enhancement: Ninigret Marsh, Charlestown, RI



## Marsh Elevation Enhancement: Ninigret Marsh, Charlestown, RI



# Hakai Magazine

Coastal Science and Societies







